

tion, and as I feel convinced of their close relationship, I have only made a microscopic examination of two of the best preserved specimens. These are somewhat intermediate between the two specimens mentioned above from Pichincha and Antisana; being compact greyish lavas, with scattered crystals of white felspar. The redder specimen—which most resembles the above rocks, does not, after what has been said, need a detailed description; it is a hypersthene-andesite with a little hornblende. The duller-coloured specimen is an augite-andesite with some hypersthene. The base of each is a clear glass, containing many very minute microliths, probably of felspar, and irregularly clouded with a grey dust and opacite.

Only one specimen remains to be described, the highest rock obtained by Mr. Whymper on Chimborazo, at an elevation of about 19,300 feet. It is a slightly scoriaceous lava, rough to the touch, almost purple-black in colour, with numerous very minute specks of a glassy felspar. Except that the base is rendered rather more opaque by disseminated opacite, it does not differ very materially from several already described. There are the usual crystals of felspar, one or two being much rounded and very full of dull glassy enclosures; there is a fair amount of augite, but no well-characterised hypersthene; so that the rock may be named an augite-andesite.

Thus the rocks of Chimborazo appear to be andesites, and rather closely related; the only variation of any importance being in the amount of hypersthene and the occasional presence of hornblende.

VII. “Notes on the Structure of some Rocks from the Andes of Ecuador, collected by E. Whymper. No. IV. Carihuairazo, Cayambe, and Corazon.” By Professor T. G. BONNEY, D.Sc., F.R.S. Received June 19, 1884. Read June 19, 1884.

I have been favoured by Mr. Whymper with some short notes on the structure and physical features of the three volcanic mountains whose rocks are investigated on this occasion, and have prefixed them to my lithological descriptions. It is remarkable what a general uniformity there is in the products of these summits of the Equatorial Andes, and this, as Mr. Whymper informs me, was so obvious that he made but small collections from the mountains which were visited during the latter part of his journey.

Carihuairazo.

“This forms the northern part of the *massif* of Chimborazo. It is separated on its south side from its great neighbour by the depression

called Abraspungo (14,479), and its northern slopes extend almost to the town of Ambato (8,500). The road to Quito winds round its eastern side, and may be considered to mark its boundaries in that direction.

"It is stated by historians that this mountain was formerly loftier than Chimborazo, and that a portion of its apex fell during a great earthquake which occurred at the end of the 17th century. I saw nothing to lead me to suppose that the mountain was at any time much loftier than at present, though it appears beyond dispute that a great fall actually occurred at the above-mentioned period. The part which fell may have formed the northern and eastern side of its crater. At the present time the three peaks which are upon its summit ridge are disposed in a horseshoe form, and I conjecture formed the southern and western sides of a crater which is now buried underneath glaciers.

"We ascended the middle peak of these three, and by mercurial barometer found that its height was 16,514 feet. Messrs. Reiss and Stübel by Δ calculated the height of Carihuairazo to be 16,752 feet. They, however, probably measured the most eastern of the three peaks, which is actually somewhat loftier than the central one.

"The lower slopes of this mountain are very swampy, from which it may be conjectured that there are not so many fissures in the soil as is common in the Ecuadorian Andes, and large thickets of trees, some of considerable age, grow high up its flanks, from which it is reasonable to conclude that it is long since the mountain was an active volcano. The rocks at the time of our expedition were much covered up by snow in the higher regions, and by earth and vegetation on the lower slopes. Such rocks as were exposed appeared closely allied to the specimens collected upon Chimborazo and the other mountains, and we only brought away specimens from the summit of the central peak. These were taken close to its highest point." (E. W.)

The rock appears to be pretty evenly jointed, it weathers brown, and breaks with a rather rough irregular fracture. The colour on this is a warm purplish-grey mottled with darker spots, and speckled with small rather light coloured crystals of felspar with a rather satiny lustre. A few minute vesicles may be perceived under the microscope. The larger felspar crystals in the slide are rather numerous, and commonly vary from about $\cdot 05$ to $\cdot 07$ inch in the longer diameter. They exhibit well developed polysynthetic twinning, and are labradorite or a closely allied form. Enclosures of glass or various microliths are occasionally seen, but the majority of the crystals are fairly clear, though a few are very dirty, and have a corroded look at the exterior. There is also present in the ground-mass a fair number of crystals of augite of a yellowish-green colour, not exceeding about $\cdot 03$ inch in length, and two or three which in structure, dichroism,

and parallel extinction agree with hypersthene. There are scattered crystals of hematite and scales of iron-glance, or possibly small augite crystals iron-stained. The ground-mass appears to be a clear glass thickly studded with dusty ferrite, and with minute crystallites in part, at least, felspar. The rock is, therefore, an augite-andesite, and bears some resemblance to the darker-coloured rock described in Part I from Pichincha.

Cayambe.

“The name Cayambe belongs both to a town and to a mountain. The summit of the latter bears north-east by east from Quito, distant 45 miles. According to my mercurial barometer observations its height is 19,185 feet, and this is remarkably close to the height obtained by Messrs. Reiss and Stubel by Δ , which was 19,161 feet. The French Academicians at the beginning of the 18th century made its elevation slightly greater than my determination, and Humboldt does not appear to have measured it. It is fourth in rank of the Ecuadorian Andes, being inferior in altitude to Chimborazo, Coto-paxi, and Antisana.

“The upper 4,000 feet of Cayambe are almost entirely covered by snow and glaciers, and such small patches of rock as are not covered are indistinguishable at the distance of a few miles. From Quito the mountain has a very noble appearance, but owing to the cloudiness of the atmosphere it is not, perhaps, seen during as much as the fifth of the year. The snow-line on Cayambe is lower than upon Chimborazo, though the former mountain is almost exactly upon the Equator, and the latter is considerably to the south of it. The upper part of Cayambe is a huge hump, and does not appear cone-shaped from most directions. At the level of 9,000 feet the mountain extends about 18 miles from north to south, and 14 to 15 miles from east to west.

“Until the time of my journey, it was conjectured that the mountain was still an active volcano. We inspected the whole of its slopes fairly well all round, and saw no open crater. It is probable that here, as in other of the Ecuadorian Andes, there was a crater near or at the summit which is now filled with snow. It is certain that Cayambe is not now an active volcano, and that it has been one in the past—the numerous streams of lava which are found upon its slopes leaving no possibility of doubt on the subject.

“Very few rocks being exposed upon the upper part of the mountain, I did here as upon Antisana, and collected specimens upon the highest attainable subsidiary peak having rocks uncovered, and from this point (Pointe Jarrin, 16,163 feet), which bears about the same relation to Cayambe as the Aiguille de Gouter does to Mont Blanc, I took specimens of the rocks *in situ*, and of the morainic fragments

lying upon them. There are no rocks exposed at the immediate summit. The highest rock we were able to obtain *in situ* was taken from a small patch of glacier-crowned cliff, some hundreds of feet below the central (and highest) peak on its western side, at a height probably of about 18,800 feet. The culmination of the mountain is an irregular ridge, several hundred yards long, having three distinct snowy bosses." (E. W.)

From the above-named lower summit—the Pointe Jarrin—Mr. Whympfer has brought nine specimens, two of which were broken from rock *in situ*. Of the seven specimens collected from the *débris* on the peak, two are rather scoriceous: one, a small fragment, is a whitish, rather glassy rock, containing small crystals of a glassy feldspar, with little plates of black mica and crystals of hornblende (?), in short, a very typical light-coloured "trachyte;" the other is a rather denser rock with a pale reddish matrix and dull whitish feldspar crystals, containing apparently less mica or hornblende. The other five are evidently varieties of a rock of the same general character; but one specimen is rather more micaceous than the rest. The remaining four may be described as generally compact rocks, in colour varying from a dull purplish to a reddish tint—the latter being probably due to an alteration in the iron constituent—in fact, I believe the differences in the colour to be mainly the results of weathering. Fairly numerous crystals of whitish feldspar, in diameter from about 0·15 inch downwards, but generally not more than 0·1 inch, are scattered in the matrix. I have examined microscopically two specimens from the *débris*, and one of the two from the rock *in situ*. I will describe first the most uniform looking and apparently best preserved specimen from the *débris*; a dull purplish-grey rock, with a fair number of small crystals of whitish feldspar, an unequal fracture, and rather clean joint faces. The base is a clear glass, so crowded with specks of opacite and ferrite and microliths of feldspar as to have a grey dusty look, except in the thinnest sections. In this are scattered the usual crystals of feldspar (plagioclastic, probably labradorite) generally fairly free from inclusions. Magnesian silicates are not very common, but I recognise both hornblende and augite, the former (occurring as the larger crystals) being somewhat black bordered and replaced by opacite, the latter clean and probably belonging to a later epoch in the consolidation of the rock. There are also to be seen scattered grains and crystals of magnetite and perhaps of hematite. The rock has a general resemblance to some of the higher fragments from Chimborazo.

The next specimen (occasionally slightly vesicular, evidently a little decomposed) is of a warm-red colour with crystals of glassy feldspar up to 0·2 inch, and a black mica, or hornblende, rather more conspicuous than in the rest. It bears a general resemblance to some of

the "trachytes" from the Euganean Hills. Under the microscope it is seen, like the last described, to have a clear base with microliths of felspar, but scattered in this are numerous rods of iron oxide, and plates of a very ferruginous mica, sometimes all but opaque. There are a few crystals of hornblende in diameter up to about .04 inch, which are strongly dichroic. There is but little if any augite.

One of the two specimens from the rock *in situ* appeared rather intermediate between the two varieties just described, and as it seemed rather decomposed was not sliced; the other, in better preservation, resembled the more mottled or streaky looking specimens among the *débris*, and afforded slight indications of a fluidal structure. This is indicated under the microscope by a "flow" of the microliths rather than by a marked striping or banding. Except for this, the matrix resembles that of the first described, with some approach to that of the second. There is nothing special to note in the larger felspar crystals which are plagioclastic, similar to those so often described; some are clear, some rather full of glass enclosures. There are fairly numerous hornblende crystals, some of an olive-green, others of a brown-green colour, strongly dichroic. Some augite crystals are certainly present, and a few of a brown mica.

Microscopically the specimen from the highest visible rocks on Cayambe barely differs from that just described, except that a fluidal structure is more inconspicuous. The result of microscopic examination is similar, the differences being but varietal; hornblende, iron-mica, and augite are present, the last being the less conspicuous constituent.

Thus the rocks of Cayambe are very uniform in character, and of the same general type as those of Chimborazo, Antisana (in part), and Pichincha (in part). They are andesites, but as they contain hornblende and augite, as well as mica, it is difficult to give them a distinctive name. I am inclined to view the first, and perhaps the third, as minerals belonging to an earlier stage of consolidation than the second: thus perhaps it is more appropriate to classify these rocks with the augite-andesites, using the word hornblendic as a qualifying epithet, except in the case of the second specimen described above, which might perhaps be termed a mica-andesite.

Corazon.

"The mountain Corazon lies almost exactly midway between Illiniza (17,400) and Atacatzo (14,892), and its summit is nearly due west of the town of Machachi, and south-south-west of Quito. It has received its name from a resemblance which it is supposed to have to a heart. Though a prominent mountain, it is one of the minor ones of Ecuador. Its height, according to my mercury barometer observa-

tions on its summit, is 15,870 feet.* I have frequently seen its entire eastern side quite free from snow, but there are upon its opposite, or western, side some large snow-beds and couloirs which are apparently permanent. The mountain therefore just enters the snow-line.

"The summit ridge is a great wall, about 250 feet long, running (approximately) north and east-south-east, having a sheer precipice on its western, and a very steep cliff on its eastern side. Possibly this wall should be regarded as a dyke. There is no regularly formed crater upon any part of the mountain.

"On the summit ridge I collected specimens of rock *in situ*, and of *débris* lying upon it. The crest of the ridge was almost covered by rock *débris* and earth. Flowering plants were growing up to the very highest point, and vegetation near the summit was more abundant than was found at equal heights on any of the other Ecuadorian Andes."—(E. W.)

From the upper part of Corazon Mr. Whymper has brought eleven specimens. Of these, ten were taken from *débris* scattered about on the summit ridge, and one was broken from the highest rock *in situ*.

The last is a scoriaceous rock with many small cavities and vesicles, darkish grey, slightly inclining to brown in colour. The microscope shows that there is present a fair amount of a glassy base, with a brown staining. This base contains numerous acicular colourless crystallites, and spots—often rather elongated—of opacite, which not seldom are clustered together, and form a kind of frame to the larger felspar crystals. These last are rather abundant, and very commonly do not exceed about .02 inch diameter, though they are occasionally considerably larger, four or five times the size. The latter often have the dirty look described above. The slide contains a few grains of a pyroxenic mineral, not very distinctly characterised.

The ten specimens gathered at different localities on the summit ridge of Corazon afford the following varieties:—

(A.) A grey pumiceous rock, larger vesicles, a little more than .1 inch diameter: volume of solid part and hollows about equal: with this may be classed a rather less vesicular specimen, with small felspar crystals; both these have a tendency to weather brown.

(B.) Four specimens of more or less scoriaceous rock of a purplish colour within, weathering externally to an Indian-red colour, and containing specks of white felspar.

(C.) Two specimens of dull grey rock with a rough fracture, speckled with small felspar crystals, and with a spotted look, one being more decomposed than the other.

* By Δ Messrs. Reiss and Stubel made its height 15,801 feet.

(E.) A dark-coloured rock with numerous specks of white felspar, rather glassy-looking outside but with rough internal fracture.

(D.) A rock similar to the last, but in shape a flattish slab rather less than half an inch thick, reminding one of the andesites and phonolites used in Auvergne for roofing purposes.

The specimens (A) were not very well suited for examination, and were clearly only scoriaceous forms of andesites; nearly allied to one of the specimens in (B); of these I have not had slides made.

(B.) The differences in these do not appear to be more than varietal; all are more or less vesicular, but in the one examined the cavities are very small and not numerous; the matrix is a dull purplish-grey, weathering rather red externally, and minute white felspar crystals are abundant. The microscopic structure differs so little from those already described that it will be enough to say that the ground-mass is rather opaque, and that there is present in it the usual plagioclastic felspar, a fair amount of characteristic augite, and a crystal or two of hypersthene.

(C.) The less decomposed of the two specimens has been examined. There are some varietal differences. The larger felspar crystals (labradorite) are not quite so numerous as in the other, while crystallites about .01 inch or rather less in longer diameter are very numerous. There is a fair amount of well-characterised augite, with grains of iron peroxide and opacite dust in a clear glassy base.

(D) does not very materially differ except that the ground-mass of the slide is rendered more opaque by the presence of opacite.

(E) is a rock of similar character, except that the base is yet more opaque. There is, however, one important distinction, that the greater part of the pyroxenic constituent appears to be hypersthene, and not augite. It is almost impossible to doubt the presence of an orthorhombic mineral in this slide.

On the summit of Corazon Mr. Whympers found two rock specimens, evidently rudely dressed by hand, which will be described in his forthcoming work on the Equatorial Andes. The material of these bore a close resemblance to the rocks described above under the group (B).

From the above remarks it would appear that the crest of Corazon consists of augite-andesites, which only exhibit slight varietal differences, except in the last case (E), where hypersthene becomes rather abundant, apparently predominating over the ordinary pyroxene. It is a remarkable fact that the exterior aspect of the rock had at once reminded me of those black, somewhat resinous-looking rocks—formerly variously called melaphyres, pitchstone-porphyrityte, &c.—which, of late years, have been so frequently proved to contain hypersthene.